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May 16, 2018

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: Written *Ex Parte* Presentation Regarding 1 dB Standard and Certified Aviation Devices, **IB Docket Nos. 11-109 and 12-340; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD 20101118-00239; SES-MOD-20121001-00872**

Dear Ms. Dortch:

Garmin International, Inc. ("Garmin") respectfully comments upon the *ex parte* presentation filed by Ligado Networks, LLC ("Ligado") on April 12, 2018 in the above captioned dockets.[1] As Garmin has long noted, it supports efforts to deploy additional broadband capacity in this nation, but not at the expense of the Global Positioning System ("GPS"). It has also been Garmin's position since mid-December 2015 that it does not object to modification applications filed by Ligado on December 31, 2015. Garmin submits this *ex parte* letter to supplement the record on two narrow points: (i) use of a 1 dB decrease in the Carrier-to-Noise Power Density Ratio ("C/N_0") as a metric to measure interference to an affected receiver (the "1 dB Standard"), as mentioned in Ligado's April 12 *Ex Parte* and addressed in the "Gap Analysis Final Report" of the National Space-Based Positioning, Navigation and Timing Systems Engineering Forum ("NPEF"), dated March 1, 2018;[2] and (ii) the extent to which issues

[1] Letter of Gerard J. Walden to Marlene N. Dortch, filed April 12, 2018, in IB Docket Nos. 11-109, *et al.* ("Ligado's April 12 *Ex Parte*"), attaching Letter of Doug Smith to Deputy Secretaries of Defense and Transportation, dated April 9, 2018 ("Smith Letter").

[2] James R. Horejsi and Kenneth A. Alexander, Memorandum for the National Coordination Office Space-Based PNT Executive Committee (March 5, 2018), available at https://www.gps.gov/spectrum/ABC/2018-03-NPEF-gap-analysis.pdf, attaching "National Space-Based PNT Systems Engineering Forum Final Report: Assessment to Identify Gaps in

related to protection of Garmin's certified aviation products remain unresolved by the NPEF Gap Analysis and the record in the above-captioned dockets.[3]

I. The NPEF Gap Analysis Is Consistent With Garmin's Position That the 1 dB Standard Is the Proper Metric for Assessing Interference.

The NPEF Gap Analysis supported use of the 1 dB Standard, noting that it was evaluating various tests of Ligado's proposals according to whether they "accept[ed] and strictly appl[ied] the 1 dB degradation Interference Protection Criteria ("IPC") for worst case conditions. (This is the accepted, world-wide standard for PNT and many other radio-communication applications.)"[4] Ligado's April 12 *Ex Parte* criticizes this approach on two grounds: (i) that this metric is inapplicable to emissions from bands adjacent to GPS; and (ii) that testing by the National Advanced Spectrum and Communications Test Network ("NASCTN") allegedly showed the metric to be neither accurate nor reliable.[5]

On the first point, Garmin agrees with a recently published U.S. Air Force analysis that the 1 dB Standard is the appropriate determinant of harmful interference to GPS and other

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Testing of Adjacent Band Interference to the Global Positioning System (GPS) L1 Frequency Band" (March 1, 2018) ("NPEF Gap Analysis").

[3] With respect to the particular service put forward by Ligado, Garmin has entered into a settlement agreement with Ligado. *See* "Settlement Agreement and Releases," by and between Garmin International Inc., and New LightSquared LLC and LightSquared Subsidiary LLC, now known as Ligado, dated December 16, 2015, attached to Letter from Gerard J. Walden to Marlene H. Dortch, IB Docket Nos. 12-340, *et al.*, December 17, 2015 ("Settlement Agreement"). In the Settlement Agreement, Garmin agreed not to object to Ligado's proposals regarding Garmin's non-certified aviation and general location/navigation lines of business as long as certain technical parameters are met. (*See* Settlement Agreement at Paragraphs 9(a) and 10(a).) At the same time, Garmin reserved the right to comment on issues related to certified aviation. (*Id.* at Paragraphs 7(d) and 9(a).) Garmin and Ligado also did not reach an agreement about whether the 1 dB Standard is an appropriate metric to use to evaluate interference to GPS in general. (*Id.* at Paragraph 6(h).) Finally, the Settlement Agreement provided that Garmin's execution of that document did not constitute an endorsement by Garmin of Ligado's proposal. (*Id.* at Paragraph 12.) While Garmin continues not to object to Ligado's proposal, it also is not endorsing it in this filing.

[4] NPEF Gap Analysis at 10-11.

[5] Ligado's April 12 *Ex Parte* at 2. The results of the NASCTN testing are available at WILLIAM F. YOUNG, ET AL., LTE IMPACTS ON GPS, NIST (2017), http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1952.pdf ("NASCTN Report").

Radionavigation Satellite Service ("RNSS") receivers, no matter whether applied to either of two types of interference: (i) out-of-band emissions ("OOBE") that emanate from services in adjacent bands but fall within the RNSS band; or (ii) overload interference that emanates from services in adjacent bands and falls outside the RNSS band.[6] In the past, much more focus has been directed to ensuring OOBE interference does not occur, since traditionally regulators have sought to group like services with similar power characteristics together in the same or adjacent band(s), separating them from other services with extreme power differences.[7]

When both types of interference occur, it is surprising that anyone would suggest that regulators considering system-level interference from a single source to GPS and other RNSS receivers can somehow separate OOBE concerns from overload interference concerns. Indeed, as technologies proliferate, experts and regulatory bodies have applied the 1 dB Standard to govern both OOBE and overload interference from services into adjacent bands, including the

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[6] *See* U.S. Air Force, SMC/GP (GPS Directorate), "Background Paper on Use of 1-dB Decrease in C/N_0 as GPS Interference Protection Criterion," June 2017, at 2, 6-9, available at www.gps.gov/spectrum/ABC/1dB-background-paper.pdf ("Air Force Analysis"). GPS, and other Global Navigation Satellite Systems ("GNSS") such as GLONASS and Galileo operate in the RNSS band (1559 – 1610 MHz).

Renowned GPS experts have also supported the primacy of a C/N_0 measurement: "An accurate measure of C/N_0 in each receiver tracking channel is probably the most important mode and quality control parameter in the receiver baseband area." HEGARTY & KAPLAN EDS., *Understanding GPS, Principles and Applications*, 2nd Ed. (Artech House, Boston, 2006), Section 5.11.1.

[7] *See* ITU Radio Regulation 4.5 which sets forth this general policy: "the frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking account of the frequency band assigned to a station, no harmful interference is caused to services to which frequency bands immediately adjacent are allocated."

Examples of instances in which the 1 dB Standard has been applied to ensuring OOBE occurring within the GPS band from services outside the band include ITU-R M.1903 and ITU-R M.1904, which are intended for performing analyses of radio frequency interference impact on RNSS and ARNS receivers from the emissions of non-RNSS sources. (The Aeronautical Radio Navigation Service ("ARNS") is a specialized terrestrial service restricted to safety-of-life use, while the Radionavigation Satellite Service ("RNSS") is for space-to-earth and space-to-space use. Both share a co-primary allocation in the 1559-1610 MHz band.)

RNSS band.[8] In such instances it is essential to evaluate the aggregate effect of these distinct types of interference originating from a common source.

As the Air Force Analysis explained, sufficient basis exists to apply the 1 dB Standard to GPS performance degradation that results from "*all interference mechanisms*" imposed by adjacent band interference.[9] According to this same report, "[a]s a practical matter, the effects of such an interference source [that is, aggregated OOBE and overload interference from adjacent services] on the RNSS receiver must be kept at least as low as the effects caused by emissions falling in the RNSS bands [that is, OOBE from adjacent services] or the existing criteria used for protecting the noise floor is [sic] effectively invalidated and rendered useless."[10]

In short, the 1 dB Standard is the appropriate metric for evaluating harmful interference from adjacent band sources because it successfully aggregates increases in the noise floor from OOBE alongside degradation from overload interference and does so in a manner even more generous than some existing ITU recommendations cited by the Air Force Analysis. Clearly, a holistic approach is the more effective and reasonable regulatory approach to resolving this issue than a piecemeal regime.

Second, the NPEF Gap Analysis' endorsement of the 1 dB Standard is not undercut by the NASCTN testing results. To the contrary, as the GPS Innovation Alliance has demonstrated in detail in the past, the NASCTN test results actually provide both direct and indirect support for use of that metric.[11]

The NASCTN tests provide <u>indirect</u> support by highlighting the extreme complexity of an approach like NASCTN's, which was focused only on measuring the effect of interfering signals on selected Key Performance Indicators ("KPIs") of GPS devices, and by showing the limitations of the data obtained from such tests. For example, although the vast majority of GPS receivers are designed and intended for non-static operation – to be expected from devices frequently used to obtain location information while moving in horizontal and vertical space – the NASCTN test method only analyzed the effect of interfering signals on *stationary* GPS

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[8] *See* ITU-R M.1461-1 at Annex 1, Section 3; ITU-R M. 2059-0 at Annex 3, Section 2 *generally*, and *specifically* Sections 2.1, 2.2; Air Force Analysis at 3 and n.4 (discussing use of 1 dB Standard for developing emission limits for LPTV stations into the GPS band). *See generally* Air Force Analysis at 2-4, 6-9.

[9] Air Force Analysis at 8 (emphasis in original).

[10] *Id.*

[11] *See generally* letter of F. Michael Swiek to Marlene H. Dortch, filed July 13, 2017, in IB Docket Nos. 12-340, *et al.* ("GPSIA *Ex Parte*")

devices. Moreover, despite the "almost 1,500 hours of testing,"[12] data were collected on only four KPIs (and even the results of these were not available for all devices). No tests were conducted to determine the effect of any detected degradation in these indicators on the actual performance of the critical applications for which the tested GPS receivers are used, such as precise machine control.

The NASCTN data, with respect to the relatively small sample of receivers that were tested, also showed a direct correlation between a 1 dB drop in C/N_0 and degradation of the KPIs analyzed; the NASCTN data, therefore, support use of the 1 dB Standard to determine harmful interference.[13] For instance, for high precision receivers, comparison of the C/N_0 plots from the NASCTN testing with the TTFF measurements for HPP and RTK receivers shows that TTFF performance degradation is concurrent with an interference-induced 1 dB drop in C/N_0.[14]

The NASCTN test results also show a close correlation between degradation in C/N_0 and the positional accuracy of the general location navigation receivers that were tested. For these receivers, the test results also highlight the significant limitation of the test methodology: simulating devices in a stationary position, which distorts the results for devices with certain filter characteristics that comprise the majority of GLN devices; nonetheless, as the GPSIA *Ex Parte* discusses in providing many examples from the NASCTN report, there is a direct correlation between a 1 dB drop in C/N_0 and degradation of the KPIs, which demonstrates the appropriateness of utilizing the 1 dB Standard.[15]

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[12] Smith Letter at 2.

[13] *See* GPSIA *Ex Parte* at 3, 9-11.

[14] *See id* at 9, citing NASCTN Report Appendix, Table 1. *See also* GPSIA *Ex Parte* at 9-10. The NASCTN testing evaluated the operation of high-performance positioning ("HPP") and real-time kinematic ("RTK") receivers with respect to both C/N_0 degradation and time to first fix ("TTFF") performance in the presence of interference. TTFF is particularly vital to users of high-precision receivers. Until a receiver attains signal tracking and position fix (*e.g.*, TTFF), it does not produce useful position measurement, so position accuracy alone is not an indicator of user performance capability. TTFF affects the *availability* of the high precision position information. Similarly, the need for increased time to re-acquire satellites and to fix cycle ambiguities on a high precision receiver can significantly degrade performance to the end-user. Many high-precision applications (*e.g.,* on heavy machinery) require *availability* near 100% for users to gain full utility and productivity from their equipment.

[15] For example, the third device under test, or "DUT 3" in the NASCTN results, illustrates how position error begins to increase at the same time C/N_0 begins to degrade in the presence of the interfering signal. (*See* NASCTN Report, Figure 6.21 (page 142), and GPSIA Ex Parte at 10.) Upon close examination, the position error begins to increase at about -20 dBm of LTE power

Without use of an objective and universal metric – such as the 1dB Standard, individual and unique test scenarios would need to be developed for every single use case. The volume of testing required across a host of subjective measures of use and experience, when multiplied by a plethora of test scenarios, would yield a vast amount of data that would be administratively staggering – and unlikely to demonstrate any universal trend or establishment of a reliable metric.

To innovate, develop products of the future, and continue to lead the world in GPS and other GNSS technologies, U.S. manufacturers need a universal, consistent, and qualifiable metric to incorporate into their product designs and testing. For U.S. devices to be internationally compatible and competitive, such a metric is essential.[16]

III. The NPEF Gap Analysis Raises Awareness of Critical Unaddressed Issues Regarding Certified Aviation Services

In criticizing the NPEF Gap Analysis for not giving "credence" to the NASCTN testing, Ligado notes that a review of the NASCTN testing results "validates the conclusion of the GPS companies that devices in *every* category of the GPS ecosystem can co-exist today or can readily be made to co-exist with Ligado's new operational parameters."[17] Yet, as the NPEF Gap Analysis acknowledges, the NASCTN tests did not examine all categories of GPS receivers – and certainly did not examine certified aviation receivers.[18] As the NASCTN report also acknowledges, NASCTN never proposed to determine compatibility; as NASCTN itself noted, it

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incident upon the DUT. This correlates well to another NASCTN figure, where DUT 3 shows a C/N_0 degradation at the same power level. (*See* NASCTN Report, at Figure 6.20 (page 141.) Shortly thereafter, DUT 3 also clearly shows how the position error grows significantly as the C/N_0 degrades in the presence of noise, actually reaching nearly 40 meters at the limit – a significant deviation for a GPS user – compared to a baseline of approximately 0.5m. (*Id.* at Figure 6.21.)

[16] The Settlement Agreement provides, if required, for specified periods with reduced power levels to permit time for design and development of hardened receivers that will be able to tolerate interference at the levels specified in the Settlement Agreement. That design change, which is ongoing at Garmin, is itself based on ensuring that GPS products are not degraded by more than 1 dB C/N_0 in the presence of Ligado signals. Garmin does not oppose the Ligado modification applications precisely because, speaking only for Garmin devices, the technical parameters to which it agreed in the Settlement Agreement were based on its own testing using the 1 dB Standard.

[17] Smith Letter at 2 (emphasis supplied).

[18] NPEF Gap Analysis at 11.

simply developed a test methodology.[19] Moreover, as noted above, Garmin, in its settlement agreement, did not reach any agreement with Ligado regarding certified aviation devices.

In explaining why certified aviation devices were not tested, the NPEF Gap Analysis noted that such "receivers did not require receiver and antenna equipment testing because the certified aviation receiver standards [already] specify the maximum tolerable interference environment to ensure all receiver functions are protected and the receivers are tested at these levels during certification testing."[20] Garmin recently reminded the Commission that it continues to have "serious concerns about the safety of certified aviation users whose devices may experience interference from Ligado operations in the 1526-1536 MHz band."[21] Garmin encourages the Commission to work closely with the Federal Aviation Administration to ensure the continued safety of those utilizing certified aviation devices.

Garmin remains committed to its Settlement Agreement with Ligado. Pursuant to Section 1.1206(b)(2) of the Commission's rules, an electronic copy of this letter is being filed for inclusion in each of the above-referenced dockets/files. If you have any questions about this filing, please contact me.

Very truly yours,

M. Anne Swanson

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[19] NASCTN Report at 1: "The methods testing, results, and analyses neither assumed nor identified pass/fail thresholds."

[20] NPEF Gap Analysis at 11.

[21] Letter from Scott Burgett to Marlene H. Dortch, July 25, 2017 in IB Docket Nos. 11-109 *et al.* at 2-3, appended to Letter of M. Anne Swanson to Marlene H. Dortch, March 19, 2018 in IB Docket Nos. 11-109, *et al.*